original specification copy

GASEOUS FUEL PRODUCTION FROM FRAGMENTARY CARBON-RICH FEEDSTOCK

TECHNICAL FIELD

This invention concerns conversion of fragmentary carbon-rich feedstock by electrical arcing into non-self-combustible gas whose air-combustion effluent is free from noxious gases and particulates.

BACKGROUND OF THE INVENTION

Underwater arcing of carbon in rod or other continuous form to generate fuel is well known, as shown by the following U.S. Patents: Richardson 6,299,738 6,299,656; 6,263,838; 6,153,058; 6,113,748; 5,826,548; 5,792,435; 5,692,459; 5,435,274; Lee *et al.* 6,217,713; Dammann 6,183,608; 5,417,817 (*et al.*); 5,159,900; Eldridge 603,058.

SUMMARY OF THE INVENTION

This invention enables commercially successful production of non-self-combustible gaseous fuel, combustible--upon addition of air or similar oxygen source--into heat and effluent substantially free of noxious gases, and free of liquid and solid particulates, by electrically converting wetted compacted fragmentary carbon-rich feedstock (e.g., anthracite, graphite, carbon residues) low in gross contaminants) into such environmentally beneficial gaseous product.

In semi-continuous operation, such conversion is achieved in a high-temperature reactor, by emplacing, compacting, and wetting such feedstock, exposing feedstock so treated to electrical arcing, thus evolving desired gaseous product, and collecting it thereabove. Any unconverted feedstock may be treated further, or may be replaced.

Feedstock is emplaced, manually or mechanically, to desired depth within such reaction zone, is wetted and is compacted therein as described below. Optimal depth depends upon carbon concentration and degree of fragmentation of the feedstock, preliminary wetting thereof, electrical conductivity of its constituent(s) so treated, the degree of indentation and/or penetration by the electrodes, and the voltage and timing of electrical power application thereto.

The extent of wetting of the fragmented feedstock may range from initial coating of its surface to complete flooding thereof, the latter generally being preferable eventually, if not initially.

Emplaced feedstock is wetted, as and when desired, via outlets from water piping in (or on) the reaction zone sidewalls, composed of heat-resistant materials and cooled by circulation of refrigerant liquids via (other) piping therein so as to protect them from the very high temperatures characteristic of electrical arcing.

This invention provides a compacting and arc-inducing module having three major components, comprising from top to bottom: (i) at fixed height, a reservoir, conveniently supported at a fixed level from the reactor sidewalls, into (and through) which water flows at a controllable rate; (ii) communicating with the reservoir base, the largest of several vertically telescoping hollow cylinders--their extension being determined by reservoir water pressure; and (iii) connecting with smallest cylinder's bottom end, hollow compressive-compacting plate (supported at controllable height determined by the extent of such telescoping) having an array of electrodes protruding downward from its lower face, and powered by positive (+) electrical connection from an (exterior) high-voltage, high-amperage source.

A pair of flexible electrical multi-conductors extend downward from laterally spaced wind-up supply rolls overhead, pass from top to bottom of the reservoir via respective vertical channels (dry) therethrough, and enter the top of a so supported hollow compacting and arcing electrode plate. Such electrical conductors terminate by connection with respective downward protruding electrodes thereof.

One or more negative (-) electrical conductors on (or in) the reactor floor provide(s) electrical grounding. Electrical arcing occurs in and through the intervening compacted wetted feedstock and thereby produces the desired gaseous product, which collects in the space above the feedstock. Such non-self-combustible gas is readily drawn off to be used then and there, or to be stored for later usage at the reactor location, or be sent by pipeline or by transport of suitable containers to storage and/or usage elsewhere.

SUMMARY OF THE DRAWINGS

Fig. 1A, 1B, & 1C are block diagrams of respective electrical, mechanical, and procedural components and steps, designated by words and/or symbols within the blocks or juxtaposed to intervening lines, for vertical compression and arcing of fragmented wet feedstock.

Fig. 2 is a sectional elevation of a reactor of this invention, featuring its feedstock-compacting and electric-arcing module having a water reservoir at a given fixed height and, suspended therefrom at controllable variable height by means of intervening telescoping cylinders, an electrode-carrying plate lowerable into compressive compacting and arcing contact with feedstock loaded therebelow.

Fig. 3 is an upward-looking sectional view taken at the level of a bottom-most cylinder in one such set, at (III-III) on Fig. 2.

Fig. 4 is an upward-looking bottom view of such electrode plate supported by the noted telescoping cylinders, at (IV-IV) on Fig. 3;

Fig. 5 is a side sectional elevation of one such electrode, with its downward protruding conical tip shown unsectioned; and

Fig. 6 is a side sectional view of an arc locus (and vicinity) between (i) a downwardly pointed conical high-voltage electrode such as shown in preceding views and (ii) an electrically grounded upwardly pointed multihedral electrode, within a mass of fragmented carbon feedstock, and exhibiting bubbles of desired gaseous product forming and/or formed alongside adjacent arcing feedstock fragments.

DESCRIPTION OF THE INVENTION

Figs. 1A, 1B, and 1C are block diagrams denoting materials and related methods by words, reference numerals, and/or other symbols. Located within or closely adjacent to actual blocks they designate named activities, materials, etc. Spaced midway between blocks, they designate flow of input or output therebetween.

Fig. 1A shows High Voltage Power Source **80** with electrical lead(s) **82** down to On-Site Rectifier **83**, leads **84** from there to Electrode Sequencer **85**, then leads **86** to Electrodes **87**.

Fig. 1B similarly shows Movable Module **20** at full height (++), with its suspended Electrode Array **89** at variable height (+/-), and further lowerable (--) into Compacting or Compressive Contact **99** with Fragmented Feedstock **100** loaded therebelow.

Fig. 1C shows Upward Evolving Gaseous Fuel As Product **104** above Arcing Compressed Feedstock **101** so Loaded into Reaction Zone, under Overhead Water Spraying **102** and/or Lateral Flooding **103**, becoming Upward Evolving Gaseous Fuel **104** and finally Collected Gaseous Product **105** for Fuel Usage **106** or Fuel Storage **107**.

Fig. 2 shows, in elevation and partly in section, reactor **10** with a U-shaped reaction zone bounded by left and right sidewalls **4** and **6** and metal electrical grounding strip **5** on floor **6** on ground **7**.

Each sidewall contains upper and lower channels **9** and **13** therein for refrigerant from conventional exterior cooling means (not shown) circulated therein to protect the walls from heat damage during the frequent adjacent high-temperature electric arcing.

Each sidewall also contains upper and lower channels **11** and **12** from a conventional external water supply (not shown) to respective lateral outlets **18**, **19** opening into the reaction zone, to enable wetting of feedstock **100** herein, from overhead and laterally, such as before and/or during--and/or after--protracted electric arcing.

Compacting and electric-arcing module **20** features reservoir **25**, itself made of (or lined with) electrically non-conductive material, and retained between the respective sidewalls via collars **23** and **27** about adjacent in-wall water pipe end portions **24** and **26**, which contain reservoir input valve **Vi** and output valve **Vo**, respectively. The reservoir contains four hydraulic lowering and raising pumps--$\mathbf{P_1}$, $\mathbf{P_2}$, $\mathbf{P_3}$, and $\mathbf{P_4}$ (latter's upper spout only shown).

Module **20** also features hollow (electrode-containing) plate **30** suspended, at adjustable height below the reservoir, by intervening sets of vertically telescoping close-fitting hollow cylinders. Each such set comprises four thereof, increasing via intermediate sizes, from **32** (the smallest) to successively larger **34** and **36** and ending with **38** (the largest) connecting at its top end to the reservoir underneath the down-spout of one of its pumps. Each of such down-spouts may (or may not) extend down into its connecting cylinder.

Connecting each of the telescoping set's largest cylinders at its top to the reservoir, and of its smallest cylinder at its bottom to a matching top opening in the hollow electrode-containing plate, completes four go/return water paths between reservoir and plate.

To apply compacting force to underlying feedstock, the hollow plate is forced down by pumping water from the reservoir (with **Vi** open and **Vo** closed) via the lower/raise pumps into and so extending the telescoping cylinders. Reversing reservoir input/output valve settings (and, thus, the pumping direction) forces water from the plate back into--then out from--the reservoir, re-raising the plate.

Product exit valve **Vx** in ceiling outlet duct **45** (cut-away view) is flanked by two wind-up rolls **44** and **46** of flexible electrical wiring, which after passing via (dry) guide tubes **74** and **76** through the reservoir from top to bottom continues to--and enters into--the top of the plate. Such wiring unwinds from its roll whenever the plate is lowered, and rewinds onto such roll when the plate rises.

Each such roll may contain not only electrode-arc wiring from a high-voltage source (**e.g., 80**, Fig. 1) to plate electrodes, but also lower-voltage leads (not separately shown) continuing upward from the plate, via at least one telescoping tubing set, to energize the reservoir pumps. The pump motors may be served even more simply by equivalent electric leads (not shown) into the reservoir from above.

As fragmentary feedstocks, even with adequate concentrations of suitable carbonaceous material, impose stringent requirements upon electric arcing, the noted step (**99**) of compacting such feedstock is undertaken mainly (not necessarily exclusively) before high-voltage arcing potential is provided to individual electrodes (**50**), as may be done randomly or in preplanned sequence. All or only some of the electrodes may be energized with fixed or varying voltage--whatever is preferred--for given feedstocks and/or during given time periods.

Fig. 3 shows, viewed upward from below [v. III-III on Fig. 2] a representative part of lower face **51** of reservoir **25** plus the (shaded) undersides **68**, **66**, **64**, and **62**--numbered from outside inward--of respective telescoping cylinders **38**, **36**, **34**, **32**, shown end-on as successively smaller concentric associated disks, each of appreciable wall thickness, in view of their load-bearing function. Centered within the smallest is similarly sturdy electrode housing **55** laterally surrounding electrically insulated electrode hot-lead **51**, shown as a similarly sturdy dot at the central axis.

Fig. 4 shows, viewed upward from below [v. IV-IV on Fig. 2], lowermost face **39** of hollow compacting-compressing plate **30**. Its array of conical electrode tips **50** resembles in appearance a 5-spotted domino face having, along each of its four edges, an added row of three electrode spots each--for a total of eleven electrodes (each corner electrode appearing in both of two intersecting rows). Though the tips are shown much alike here, their actuation at unlike voltages and/or for unlike time durations will erode them unevenly.

Fig. 5 shows in longitudinal section, on a much larger scale, electrode housing **55** of Fig. 3 sectioned lengthwise, surrounding its (insulated) hot-wire **51**, whose bottom end **56** seats in indentation **57** in the top of (otherwise unsectioned) conical electrode **50**.

Housing **53** (sectioned lengthwise) exhibits lateral outlets or "weep holes" with flow arrows therethrough and into the surrounding water, whether within the plate or below it (as shown here). Any water so weeping into the plate may re-enter the reservoir via the cylinders, whenever subsequently re-telescoped. Water weep-exiting below the plate may be converted by the arcing into steam or even (along with feedstock carbon) into the desired gaseous product.

Fig. 6 shows electrical arc site between a downward protruding conical electrode tip **49** spaced above an upstanding quadrihedral tip **51** grounded by plate-like electrode **7** [in floor **8**, not shown here]. As such arc **90** is blinding, it appears as a blank space (of rays).

Adjacent fragments of wet feedstock are shown as dark irregular blobs on which beads of desired gaseous product are likely to appear as adjacent bubbles (**99**), which may collect initially thereon or therebetween. Such bubbles initially may expand in place by merging with adjacent visible bubbles (or invisible quantities) of gas which will rise and join otherwise unseen volumes thereof as an invisible blanket of the desired gaseous product overlying whatever impurities or unconverted feedstock may remain thereunder.

Such product may be collected conveniently by first flooding the reaction zone--if not already flooded--via inwall water outlets, then opening outlet valve **Vx** in cover or roof 59, which otherwise seals the space overhead. A preferably oil-free gas-compressor (not shown here) is useful in forwarding the collected gaseous product to a storage container or to a usage location, if so desired.

As fragmentary feedstocks, even with adequate concentrations of suitable carbonaceous materials, impose stringent requirements upon electric arcing, the noted step (**99**) of compacting such feedstock is undertaken mainly (not necessarily exclusively) before high-voltage arcing potential is provided to individual electrodes (**50**), as may be done randomly or in computerized sequence. During some or all of the time, some or all of the electrodes may be "hot"--whether fixed or varying in voltage--as may be preferred for a given feedstock.

Initial injection (as via in-wall water piping **54**, **56**) of a slightly conductive--otherwise inert--gas, such as helium or argon, and/or even so innocuous an electrolyte as acetic acid, may help to initiate, or even to maintain, the essential electrical arcing.

After feedstock arcing is deemed satisfactorily completed in any single run, voltage to the electrodes in the module plate is discontinued, and the module plate is raised from the feedstock remnants by withdrawing water from the extended telescoping cylinders.

The feedstock residue then may be recompacted to be treated further, or may be removed so as to be replaced by a new batch of the same or equivalent feedstock of fragmented carbon-rich composition. Such an interim also enables personal scrutiny or any pre-scheduled replacement of any excessively corroded or non-performing electrode. Though made of tungsten or its alloys with other stable heavy metals any electrode will corrode and/or wear away during repeated arcing.

The space overhead can be diminished by replacing the indicated fixed ceiling by a downwardly movable false ceiling--and by raising it gradually as the desired gaseous product is formed underneath it.

Additionally or alternatively, the feedstock may be blanketed with another relatively inert gas (e.g., carbon dioxide) or by otherwise delaying gaseous fuel production until substantially all air in the reaction zone has been superseded by blanketing or otherwise.

The preferably refrigerant-cooled reactor walls are composed of readily available high-temperature-resistant material(s), preferably ceramic or stone--or some combination thereof--thus rendering them adequately stable despite electric-arcing, wherein temperatures of thousands of degrees may be reached and persist for lengthy periods.

The conical and/or tetrahedral feedstock-contacting electrodes shown herein preferably comprise tungsten or its durable heavy-metal alloys selected to withstand the encountered electric-arcing and to provide an adequately functional operational lifetime. Nevertheless, they preferably are mounted for ready replacement, as may be needed.

Useful variations may be made in the subject invention, as by adding, combining, deleting, or subdividing apparatus, compositions, parts, or steps, while retaining many advantages and benefits of the herein described invention--itself being defined more specifically, as to its wide variety of useful aspects, in the following claims.